

Aug. 19, 1958

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2,848,632

SPIRALED MAGNETIC FIELD SYNCHRO

Filed April 29, 1957

2 Sheets-Sheet 1

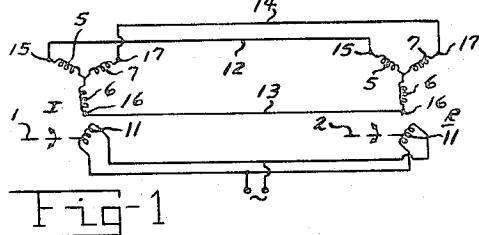


Fig-1

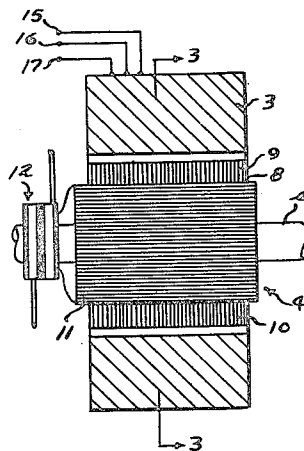


Fig-2

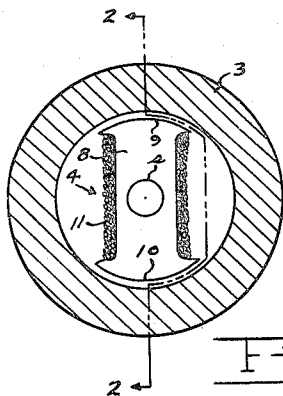


Fig-3

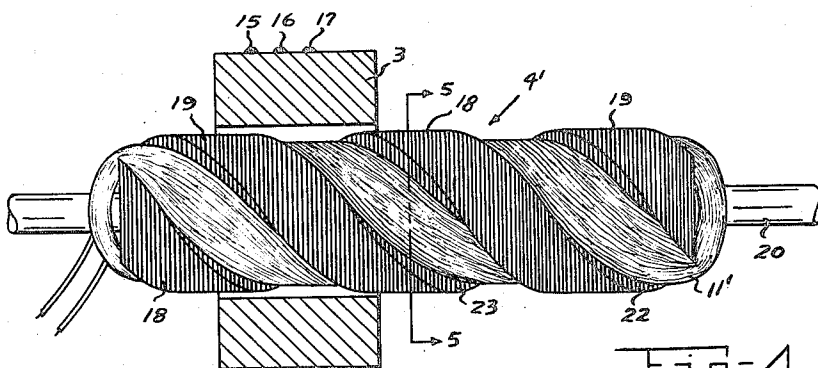


Fig-4

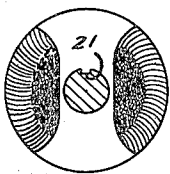


Fig-5

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2 Sheets-Sheet 2

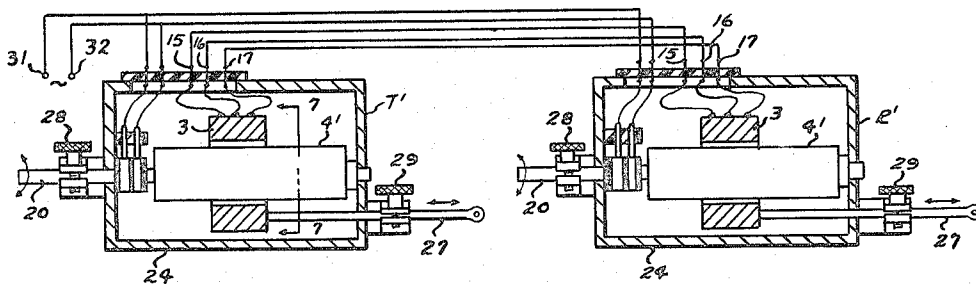


Fig-6

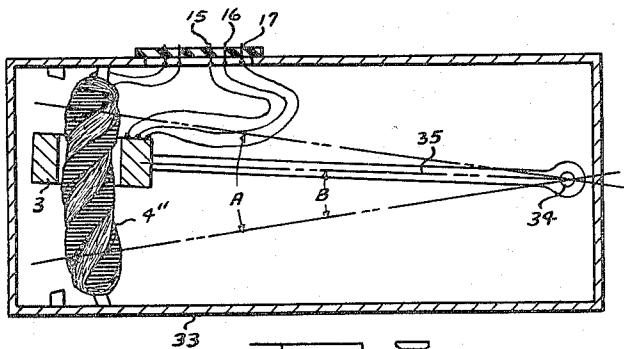


Fig-8

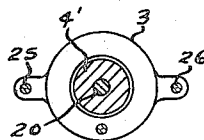


Fig-7



Fig-9

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SPIRALED MAGNETIC FIELD SYNCHRO

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9 Claims. (Cl. 310—27)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without payment to me of any royalty thereon.

This invention relates to synchros, or self-synchronous electrical devices, for transmitting motion or positional data. It is the principal object of the invention to provide a synchro capable of transmitting linear motion or positional information directly, without resort to gears, cams or other mechanical devices for converting rotary motion into linear motion. A further object of the invention is to provide a synchro capable of converting rotary motion to linear motion, linear motion to rotary motion and rotary motion to rotary motion in any desired angular ratio, and in which the motion conversions can be made non-proportional if desired. The described synchro is electrically similar to and can be used in conjunction with synchros of conventional type used to transmit angular information.

Briefly the synchro consists of an outer three-winding core surrounding and coaxial with an inner core having two salient poles and a single winding as in a conventional synchro. The described synchro differs from the conventional synchro, however, in that the inner core is axially elongated and the two faces of the salient poles follow helical paths about the axes of the core. Therefore, when the inner core is moved axially relative to the outer core the two salient poles, in effect, rotate within the outer core having an effect electrically similar to the rotation of the inner core in a conventional synchro. Therefore, if two of the described synchros are connected together and energized in the manner of conventional synchros, the inner cores will assume similar axial positions relative to their outer cores and any relative axial motion between the inner and outer cores of one synchro will produce similar relative axial motion in the other synchro. On the other hand, if relative axial movement of the cores is prevented in the two synchros, relative rotation of the cores of one synchro will produce similar relative rotation in the other synchro the same as with conventional synchros. It is evident, therefore, that by the proper combination of permitting and preventing relative axial and rotational movement of the cores, linear motion may be converted to angular motion and vice versa.

A more detailed description of this invention will be given in connection with the specific embodiments thereof shown in the accompanying drawing, in which—

Fig. 1 shows a conventional synchro circuit,

Figs. 2 and 3 illustrate structural details of a conventional synchro,

Figs. 4 and 5 illustrate the construction of the inner core of a synchro in accordance with the invention,

Fig. 6 shows a synchro circuit employing synchros constructed in accordance with the invention,

Fig. 7 illustrates a manner of supporting the moving outer core of the synchro,

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Fig. 8 illustrates an arrangement for transmitting or receiving angular motion in a ratio other than unity, and

Fig. 9 shows a core in which the pitch of the pole face helices varies along the axis.

Referring to the schematic diagram of a conventional synchro system shown in Fig. 1, the shaft 1 of transmitting synchro T is firmly driven and constitutes the input to the system. The shaft 2 of the receiving synchro R is caused to follow the angular movements of shaft 1 and constitutes the output of the system. The transmitting and receiving synchros are electrically and mechanically similar, except that the receiving synchro is usually equipped with a damping device and may have bearings of lower friction than are required in the transmitter. The general physical form of a conventional synchro is illustrated in Figs. 2 and 3. The essential elements are an outer cylindrical magnetic core assembly or stator 3 and an inner magnetic core assembly or rotor 4 mounted on shaft S which is concentric with the outer core assembly. The stator 3 is normally mounted in a housing which supports shaft S in suitable bearings, neither shown in the drawing. The stator 3 consists of a laminated slotted core carrying the three equal windings 5, 6 and 7 (Fig. 1) spaced 120° apart. The windings may be Y-connected, as in Fig. 1, or delta-connected, the stator being in all respects similar to the stator of a 3-phase motor or generator. The rotor consists of a laminated core 8 having two salient poles, the faces of which are designated 9 and 10. The core is wound with a single winding 11 to which connection is made by slip rings and brushes generally indicated at 12.

Returning to Fig. 1, when the rotor windings 11 are energized with alternating current, voltages are induced in the stator windings by transformer action. The amplitudes and phases of these alternating voltages depend upon the position of the rotor winding relative to the stator, however, the phase of the voltage in any winding will always be the same as or opposite to that of the power source voltage applied to the rotor windings. If the rotor windings 11 are energized in parallel, as shown, and shaft 1 is firmly held, the rotor of synchro R will rotate to the position at which the voltages induced in the stator windings of synchro R are of the same amplitude and phase as the voltages induced in the corresponding stator windings of synchro T. When this condition exists, the currents in connecting lines 12, 13 and 14 are zero and the system is in a state of equilibrium. If an angular motion is imparted to shaft 1 changing the position of the rotor winding 11 of synchro T, rotor winding 11 of synchro R is forced through an equal angular displacement to restore the condition of equilibrium. Therefore shaft 2 is made to follow the angular movements of shaft 1.

The construction of a synchro in accordance with the invention is shown in Fig. 4. The outer magnetic core assembly 3 is identical to that of the conventional synchro described above, connections to the three windings being made at terminals 15, 16 and 17. The inner magnetic core assembly 4' is similar electrically to the conventional synchro rotor but differs structurally. It is similar in that the core has two salient poles and a single winding. It is different in that the core is considerably longer axially than the outer core assembly and in that the two salient pole faces follow diametrically opposite helical paths in the direction of the axis. The helical pole faces are designated 18 and 19 in Fig. 4. The core assembly may be constructed by placing a number of laminations shaped, for example, as shown in the sectional view of Fig. 5, over shaft 20 each being rotated slightly with respect to the preceding laminations. A key in each lamination may cooperate with a spiral slot 21

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in the shaft to angularly position the laminations, as shown in Fig. 5, the shaft being slightly larger inside the laminations. The single winding 11' is placed in the two diametrically opposite spiral slots 22 and 23 that result from the shape of the laminations and their angular displacement.

If the outer and inner core assemblies of Fig. 4 are mounted so as to permit relative axial movement but not relative rotation, the relative axial movement has the same electrical effect as rotation of the rotor in a conventional synchro. In other words if coil 11' in Fig. 4 is energized with alternating current and the terminals 15, 16 and 17 of outer core assembly 3 are connected to the corresponding terminals of a second identical outer core assembly, the direction of the resultant magnetic flux in the second assembly will rotate in response to the axial movement of inner core assembly 4' relative to its associated outer core assembly 3. The axial length of the core of the inner core assembly 4', the pitch of the pole face helices and the axial length of the core of outer core assembly 3 are normally correlated so that axial movement of assembly 4' relative to assembly 3 from one limit to the other results in 360° of rotation of the flux deviation in the second outer core assembly.

The construction of Fig. 4 has the further characteristic that, with relative axial movement prevented, relative rotation of the outer and inner core assemblies 3 and 4' produces the same voltages at terminals 15, 16 and 17 as would be produced at the corresponding terminals of a conventional synchro by turning its rotor. Therefore a synchro of the type shown in Fig. 4 may be used in conjunction with another similar synchro for linear-to-linear, linear-to-rotary, rotary-to-linear and rotary-to-rotary motion transmission depending upon the types of relative motion permitted between the outer and inner core assemblies. These uses are illustrated in Fig. 6.

In Fig. 6, synchro T' may be considered the transmitter and synchro R' the receiver. Both synchros are illustrated as being alike, although in a practical embodiment the receiver may differ mechanically from the transmitter, as in conventional synchros, in having means to reduce friction and provide damping. Disregarding these possible differences, each synchro is constructed in accordance with Fig. 4. The inner magnetic core assembly 4' is journaled in the housing 24 and the outer magnetic core assembly 3 is supported within the housing in a manner to permit axial movement relative to inner element 4' as by rods 25 and 26, shown in Fig. 7. A rod 27 extends through the housing for coupling core assembly 3 to an external mechanism. Clamps 28 and 29 are provided for locking core assemblies 4' and 3 against rotation and axial movement, respectively, if desired.

For linear-to-linear motion transmission, clamps 28 in each synchro are engaged to prevent rotation of the inner core assemblies 4' and clamps 29 are released to permit axial movement of the outer core assemblies 3. With rod 27 of T' firmly held by external means and the windings of the inner core assemblies 4' energized by the application of alternating voltage to terminals 31-32, the core assembly 3 of R' will assume the position axially of inner core assembly 4' at which the direction of the resultant flux relative to the three windings of outer assembly 3 is the same as in T' and at which the phase of the flux is the same as in T'. If the core assemblies 4' of T' and R' were initially clamped in the same angular positions, the above conditions exist when the outer core assembly 3 of R' has the same axial position relative to inner core assembly 4' that core assembly 3 of T' has relative to its associated core assembly 4'. For linear motion transmission, therefore, rod 27 of T' is the input to the system and any axial movement of this rod in the direction of the arrows is followed by a corresponding movement of the rod 27 of R'. The ratio in which the linear motion is transmitted is determined by the relative pitches of the helical pole faces in the two synchros.

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If the pitch is the same in the receiver as in the transmitter the transmission ratio is unity, if the receiver pitch is less than that of the transmitter the ratio is less than unity and if the receiver pitch is greater than that of the transmitter the ratio is greater than unity. Nonproportional transmission of linear motion is also possible. This is accomplished by having the pitch of the helical pole faces in either the transmitter or receiver, or both, vary along the axis in a desired manner. Fig. 7 shows the inner core assembly 4' designed so that the pitch decreases from left to right along the axis.

In linear-to-rotary motion transmission clamp 28 of T' and clamp 29 of R' are engaged while clamp 29 of T' and clamp 28 of R' are disengaged. With rod 27 of T' as the input, movement of this rod in the direction of the arrows causes rotation of inner core assembly 4' and shaft 20 of R'. Again the ratio of motion transmission is determined by the pitch of the helical pole faces of core assembly 4' in T'. Also, the motion transmission may be made nonproportional by having the pitch of the helical pole faces in core assembly 4' of T' vary along the axis.

Rotary-to-linear transmission may be accomplished by engaging clamp 29 of T' and clamp 28 of R', and disengaging clamp 28 of T' and clamp 29 of R'. Rotation of shaft 20 of T' in this case causes axial movement of outer core assembly 3 and rod 27 of R'. The transmission ratio, as before, can be controlled by controlling the pitch of the helical pole faces in the inner core assembly 4' of R'. Also, as before, the motion transfer may be made nonproportional by having the pitch of the helices of 4' in R' vary along the axis.

It is also possible to have both rotary and linear inputs to T'. In this case, one or the other of clamps 28 and 29 of R' is engaged depending upon whether rotary or linear output is desired. The output of R', either linear or rotary, is the sum of two components, one derived from the rotary input to T' and the other derived from the linear input to T'.

With clamps 29 engaged and clamps 28 disengaged in both T' and R', rotary-to-rotary motion can be accomplished in the same manner as in a conventional synchro system. With shaft 20 of T' as the input of the system, any angular displacement of this shaft is accompanied by an equal angular displacement of shaft 20 of R'. Therefore, with axial motion of outer core assembly 3 prevented by clamp 29 and with clamp 28 released permitting rotation of shaft 20, the synchro is the electrical and functional equivalent of a conventional synchro and whenever so used in the preceding examples may be replaced by a conventional synchro. Operation of synchros of the type shown in Fig. 6 in the same system with conventional synchros is therefore entirely feasible.

It is sometimes desirable to transmit angular motion in a ratio different from unity. This may be accomplished by the embodiment of Fig. 8. In this device the inner magnetic core assembly 4'' is rigidly attached to the housing or body member 33 and is similar in all respects to core assembly 4' of Fig. 4 except that it may be curved in an arc centered on shaft 34 in order to permit a minimum air gap to the outer core assembly 3 which is carried by arm 35 attached to shaft 34. Assuming R' in Fig. 6 to be replaced by the device of Fig. 8, clamp 29 of T' to be engaged and clamp 28 of T' to be disengaged, rotation of shaft 20 of T' through 360° will cause shaft 34 to rotate through the angle A. Therefore, rotation of input shaft 20 through a given angle from its zero position causes shaft 34 to rotate through an angle B equal to $A/360$ times the given input angle, the transmission ratio $A/360$ in this case being less than unity. For a transmission ratio greater than unity, the device of Fig. 8 may be made the transmitter, replacing T' in Fig. 6, clamp 29 being engaged and clamp 28 being disengaged in R'. In this case rotation of input shaft 34 through an angle B causes shaft 20 of R' to rotate through an angle equal to $360/A$

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times B , the transmission ratio $360/A$ now being greater than unity. The magnitude of the transmission ratio depends upon the length of arm 35 and the pitch of the helical pole faces of core assembly 4". Also, the transmission may be made nonproportional by having the pitch of the pole faces of 4" vary along the core axis as in preceding examples.

The device of Fig. 8 may also be used with synchros of the type shown in Fig. 6 used as linear transmitters and receivers, i. e., with clamp 29 engaged and clamp 28 disengaged, for linear-to-rotary and rotary-to-linear transmission. The effect of pole face helix pitch on transmission ratio and the effect of a variation in pitch along the core axis in producing nonproportional transmission are the same in these applications as in the preceding examples.

I claim:

1. A synchro having coaxial outer and inner magnetic core assemblies in which the transversely magnetized core of the inner core assembly has two salient poles, the faces of which are in the form of diametrically opposite helices of greater axial extent than the magnetic core of said outer assembly, and the inner surface of said outer magnetic core assembly is substantially cylindrical.

2. A synchro having coaxial outer and inner magnetic core assemblies in which the transversely magnetized core of the inner core assembly has two salient poles, the faces of which are in the form of diametrically opposite helices of greater axial extent than the magnetic core of said outer assembly, the inner surface of said outer magnetic assembly being substantially cylindrical, and means providing for relative axial movement of said core assemblies.

3. A synchro having coaxial outer and inner magnetic core assemblies in which the transversely magnetized core of the inner core assembly has two salient poles, the faces of which are in the form of diametrically opposite helices of greater axial extent than the magnetic core of said outer assembly, the inner surface of said outer magnetic core assembly being substantially cylindrical, and means providing for both relative axial movement and relative rotational movement of said core assemblies.

4. A synchro having coaxial outer and inner magnetic core assemblies in which the magnetic core of the inner core assembly has two salient poles, the faces of which are in the form of diametrically opposite helices of greater axial extent than the magnetic core of said outer assembly, and means restricting relative movement of said core assemblies to relative axial movement.

5. A synchro having coaxial outer and inner magnetic

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core assemblies in which the magnetic core of the inner core assembly has two salient poles, the faces of which are in the form of diametrically opposite helices of greater axial extent than the magnetic core of said outer assembly, means providing for both relative axial movement and relative rotational movement of said core assemblies, and independently actuatable means for locking said core assemblies against either of said relative movements.

6. A synchro having coaxial outer and inner magnetic core assemblies in which the magnetic core of the inner core assembly has two salient poles, the faces of which are in the form of diametrically opposite helices of greater axial extent than the magnetic core of said outer assembly, the pitches of said helices varying equally along said inner core assembly.

7. A synchro having coaxial outer and inner magnetic core assemblies in which the magnetic core of the inner core assembly has two salient poles, the faces of which are in the form of diametrically opposite helices of greater axial extent than the magnetic core of said outer assembly, a shaft, a body member fixedly supporting said inner core assembly and rotatably supporting said shaft so that the axis of said core assemblies lies in a plane normal to said shaft, and an arm having one end attached to said shaft and the other end attached to said outer core assembly.

8. Apparatus as claimed in claim 7 in which said inner core assembly has an arcuate shape of which said shaft is the center.

9. A synchro having an outer magnetic core assembly comprising a magnetic core having a cylindrical opening therein and having three windings with their centers equally spaced about said opening; an inner magnetic core assembly situated within said opening and concentric therewith, comprising a magnetic core of greater length than the core of said outer core assembly having two salient poles and a single winding, the faces of said poles being in the form of diametrically opposite helices; and means providing for relative axial movement of said core assemblies.

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